other species of *Plagiochila* in the Western Ghats as characterized by exclusively bipinnately branched (terminal) plants with oblong-ovate leaves having truncate apex, and margins are rather jagged with up to 11-12 teeth. However, vestigial underleaves are also found, only at the apical shoots. The leaves produce numerous propagules on the ventral surface and one-celled to juvenile multi-celled plantlets may be seen on the same leaf.

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25. LATIN DIAGNOSIS OF *SPIRULINA* (=*ARTHROSPIRA*) *MAHAJANI* MAHAJAN[1]

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In an earlier paper Mahajan, S.K. (2004): A new species of *Spirulina* (=*Arthrospira*) *mahajani* Mahajan from Khargone, Madhya Pradesh. *J. Bombay Nat. Hist. Soc. 101(2)*: 294-295. I had given the details of place, date of collection and location of type material in English, but did not include these details in the latin diagnosis, I wish to remedy this omission by giving a latin rendering of these details here.

Spirulina mahajani Mahajan sp. nov.

Trichomata veneta, libre natanti, non constricta, 4.9-5.6 µm lata, extreme leviter angustiora, ordinate et laxe 3-5 spirata (3.4-5.1 spirata), spirae latitudines fere aequalium, 33-44 µm lata et inter se 39-99 µm distantia; cellulae subquadratae, 2.1-3.6 µm longae; vacuolae gaseosae in cytoplasma uniformiter distributae; cellulae extremorum simplices et calyptra singulari plane conica.

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26. FIG TREES (*FICUS*), CAPTIVE ELEPHANTS, AND CONSERVATION OF HORNBILLS AND OTHER FRUGIVORES IN AN INDIAN WILDLIFE SANCTUARY[1]

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Introduction and background

The endangered Great Pied Hornbill *Buceros bicornis* (GPH) is the largest (length: 120 cm; mass: 3 kg) of the nine species of hornbills (Bucerotidae) in India (Ali and Ripley 1987). Its diet is principally fruits, with a preponderance of figs (*Ficus*) (Kannan 1994; Kannan and James 1997, 1999). The species is affected by a variety of problems ranging from destruction of its wet forest habitat to poaching of adults and squabs from nests (Ali and Ripley 1987), and is listed in Schedule I (most protected) of the Indian Wildlife (Protection)

Act of 1972 (MoEF 2006). The bird is almost always seen foraging or nesting in lofty trees of deep wet-evergreen or moist-deciduous hill forests (Hume 1890; Ali 1936; Ali and Ripley 1987; Kemp 1995), and is therefore apparently dependent on mature old-growth vegetation. No systematic study has been attempted to quantify the foraging habitat preferences of this species. We hereby present quantitative information on a critical component of the foraging habitat-niche of the Great Pied Hornbill (GPH). As explained below, this information enabled us to lobby the Tamil Nadu Forest Department (TNFD) into adopting a policy – a key management strategy to help in conservation of the species.

There is a plethora of evidence in the literature on the importance of *Ficus* as a fruit source for the maintenance of several vertebrate populations (Janzen 1979; Gautier-Hion 1980; Lambert 1989; Lambert and Marshall 1991; Borges 1993), including hornbills (Leighton and Leighton 1983; Kemp 1995; Kinnaird *et al.* 1996; Kannan and James 1997, 1999; Datta and Rawat 2003; James and Kannan 2007; Kannan and James 2007). For the past century or so, Teak (*Tectona grandis*) lumbering operations in the Indira Gandhi Wildlife Sanctuary (IGWLS) in the Anaimalai Hills (Tamil Nadu) of southern India have been assisted by domestic elephants stationed in the protected forests. As a part of the official program to maintain them, mahouts have been traditionally authorized to feed elephants with their favoured forage, which consists of fig leaves harvested from surrounding forests. This practice helped conserve precious funds that would otherwise be allocated for procuring elephant feed.

Between 1991 and 1993, we observed that numerous fig trees inside IGWLS had been lopped repeatedly to feed the approximately 30 elephants stationed in the Sanctuary. Many fig trees in the Top Slip area (Ulandy range) showed telltale signs of having been lopped in the recent past: stunted appearance, truncated boles and branches, and absence of fruiting (despite two years of constant monitoring). The TNFD regarded lopping to be relatively harmless to the trees as it was seldom lethal. The elephants aided in lopping and transporting the bales of *Ficus* foliage from the forests to various elephant camps in the Sanctuary. We also observed that many local avian frugivores, especially GPH, relied heavily on fig fruits for food. Over 90% of all GPH tree visits during one year (September 1991 to August 1992) were to fig trees, compared to 55.7% for four other avian frugivores during the same period, and nearly a quarter of the resident avifauna ate figs (Kannan and James 1999). Considering such heavy dependence on figs by GPH and many other local wildlife species, we collected quantitative data to demonstrate the importance of large fig trees in the foraging habitat of the hornbill. Our goal was to provide the TNFD with data on size of fig trees suitable for GPH, and thereby convince them of the potential negative effects of the *Ficus*-lopping practice on GPH and other vertebrate frugivores.

Study area and methods

The study was conducted in the Top Slip area of the 1,250 sq. km IGWLS. The Sanctuary is a vast mosaic of moist-deciduous or evergreen forests, tea and teak plantations and human settlements (refer Kannan and James 1997, 1999 for more information about the area).

We developed a profile of the foraging habitat by measuring different vegetational characteristics around each of 20 fig trees used by the GPH for foraging, following the approach proposed by James and Shugart (1970) and adopted by Mudappa and Kannan (1999) and James and Kannan (2009, in press). Circular vegetational plots measuring 0.07 ha (radius 15 m) were established around the tree, and 15 vegetational characteristics (Table 1) were measured within these plots. Shrub density was measured by counting stems intersecting a meter-wide stick held at waist height (1 m) along four orthogonal transects established at the centre of each plot. Heights were measured using a clinometer. Canopy and ground cover were determined by making 40 overhead and ground sightings for presence of green vegetation sighted at the cross-wires of a sighting tube at random points along the transects. Emergence of the centre tree is defined as the projection of the centre tree above the rest of the canopy. Data gathered from the foraging plots were compared with an equal number (20) of control samples in which the centre fig tree was chosen by pacing 75 m away from the foraging fig tree in a randomly chosen direction. The nearest fig tree at the end of this distance with a diameter (DBH) of 20 cm or above was used as centre tree, and the vegetational factors measured at the foraging site were measured in a plot centered on the control tree. We observed that 75 m to the control plot was a sufficient distance to evade the forest structure influence of the foraging plot, but still within the same general forest type, and our findings, which follow, showing significant difference between foraging and control plots proved we were correct. We chose 20 cm as the minimum DBH for the control fig trees because that was the minimum size in which fig trees were observed to bear fruit in the area (Kannan and James 1999). All the control trees showed no signs of lopping, and GPH were not observed to forage in those trees. Our aim was to compare fig trees used by GPH, with fig trees available and unused in the area (control fig trees), to test the hypothesis that hornbills choose exceptionally large trees for foraging. Such a comparison between used and non-used trees is important to delineate habitat factors that are crucial for hornbill foraging habitat selection.

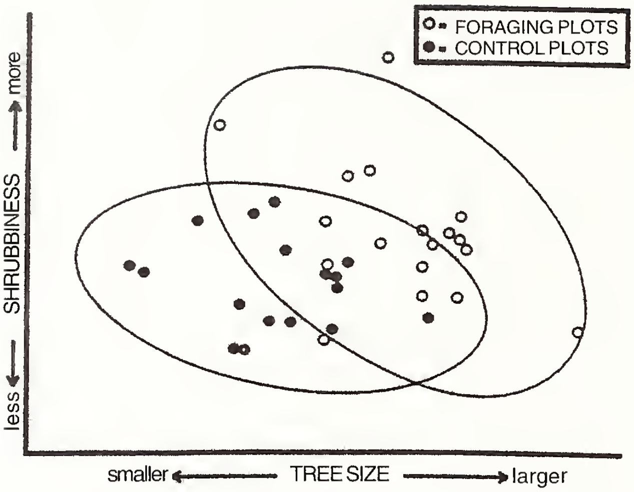

Fig. 1: Ordination, with 95% confidence ellipses, of fig tree foraging plots used by the Great Pied Hornbill and control fig tree plots, based on the scores of the first (tree size) and second (shrubbiness) Principal Components.
(The number of circles, both shaded and open, number less than the requisite 20 each because some plots were so similar that the circles were superimposed.)

We analyzed data using univariate Analysis of Variance (ANOVA) to determine which habitat characteristics used by the hornbill for foraging was significantly different from those of control samples. Principal Components (PC) Analysis (Morrison 1967) was performed to determine the most important factors delimiting the habitat niche of the species. Multivariate Analysis of Variance with step-wise Discriminant Function Analysis (Cooley and Lohnes 1971) was also performed to identify the critical vegetation characteristics involved in separating foraging sites from control ones. All these tests were done using SAS Institute (1985) software.

Results

Results of Analysis of Variance (ANOVA) of 15 vegetational characteristics measured in foraging and control plots (Table 1) showed that the following factors had values that were significantly higher in foraging plots than in control plots: shrub density, average canopy height, tallest tree height, centre tree height, centre tree diameter, and emergence of centre tree above forest canopy. Except shrub density, all other significant parameters represent size of centre tree, indicating that large trees are a critical part of the foraging habitat of the hornbill. PC analysis too emphasized the importance of foraging tree size in hornbill foraging habitat selection. Accounting for 77% of the total variance in the data, the first PC (PC I, Table 1) was highly correlated with the vegetational characteristics named above that directly relate to size and maturity of centre tree: tree height, centre tree diameter, canopy height, height of tallest tree in plot, and emergence of centre tree. PC I could thus be named "centre tree size." PC II, which accounted for an added 14 percent of the total variance (Table 1) could be called 'shrubbiness', since it was correlated heavily with shrub density. Together, PC I and PC II explain more than 90 percent of total variance in the vegetational data measured.

The foraging and control fig trees were clearly separated (Fig. 1) along the environmental gradient (PC I) representing tree size, with foraging plots positioned towards larger centre tree size, and control plots scattered towards the other end of the continuum. This portrayal reinforces the importance of large trees in selection of foraging sites by GPH. Although not obvious visually, the increased shrubbiness of foraging plots is evident by drawing a horizontal line across the figure so that half the combined circles are above the line, half below. Note that about twice

Table 1: Vegetational characteristics that differed significantly⁺ between fig tree foraging sites used by the Great Pied Hornbill and control fig tree sites

Vegetational characteristic	Foraging plot mean (n=20)	Control plot mean (n=20)	P*	Correlations with Principal Components (PC)	
				PC I	PC II
Shrub density (per 60 sq. m)	72.5	53.3	0.01	0.16	<u>0.54</u>
Average canopy ht.(m)	29.7	25.7	0.005	<u>0.74</u>	-0.24
Tallest tree in plot (m)	35.8	30.4	0.007	<u>0.81</u>	-0.22
Centre tree ht. (m)	35.1	25.4	0.0001	<u>0.96</u>	-0.18
Centre tree diameter (m)	1.73	1.04	0.0001	<u>0.74</u>	0.098
Centre tree emergence (m)	5.4	-0.28	0.001	<u>0.78</u>	-0.06
Percentage of total variance				77	14

*Univariate Analysis of Variance (ANOVA)
⁺Other characteristics that were measured but did not differ significantly were: per cent canopy and ground cover and number of trees in the plot in the diameter (DBH) classes (cm) 15-30, 30-45, 45-60, 60-75, 75-90, 90-105, and >105.
Underlined values in Principal Components (PC) analysis represent high correlations with their respective PCs.

as many foraging plots than control plots are above the line, indicating increased overall shrubbiness in the foraging plots. Twice as many control plots compared to foraging plots are below the line indicating overall decreased shrubbiness in the control plots.

Three vegetational characteristics were identified by Stepwise Discriminant Function Analysis as most important in providing separations between foraging and control plots. These were: centre tree height, canopy cover, and shrub density ($P = 0.0001$, 0.0129, and 0.0002 respectively), the first two emphasizing the importance of tree size in hornbill foraging.

Discussion

Lopping fig trees to feed captive elephants has apparently been practiced in the IGWLS since the beginning of lumbering operations in late 19th and early 20th century. The findings of this study, and those of concurrently conducted phenology and GPH feeding ecology studies (Kannan 1994; Kannan and James 1997, 1999, 2007) highlighted the importance of large fig trees for GPH foraging, and the 'keystone' (Lambert and Marshall 1991) nature of *Ficus* in the conservation of hornbills and other vertebrate frugivores. In our study area, fig fruits were available year-round, and their availability when other fruits were scarce made them especially important for frugivores (Kannan and James 1999). Moreover, the pattern of fig production significantly increased during the dry and hot months between February and May, coinciding with the breeding season of the GPH (Kannan and James 1999), when the majority of food items (72.9%) delivered by parent hornbills to confined nest inmates were figs (Kannan and James 1997). Non-fig fruits exhibited highly seasonal fruiting patterns, being available only during the dry and hot season. Our findings prompted the TNFD into mandating a total ban on fig tree removal and lopping inside IGWLS in May 1992. Upon prompting from us, the policy was reinforced *via* a circular dated May 12, 1995 from Mr. M. Krishnakumar, I.F.S., Wildlife Warden of IGWLS, to all Range Officers in the sanctuary (M. Krishnakumar, pers. comm.). As of 2001, that directive was still the policy in the department (N. Loganathan, TNFD, pers. comm.). Although violations of the ban still occur sporadically (R. Natarajan, IGWLS, pers. comm., 2001), lopping is no longer systemic in the IGWLS. In addition, the TNFD embarked on (in 1993) a program of trail-side planting 2,000 *Ficus* saplings in the Top Slip area of IGWLS, although none survived because of grazing by wild mammalian herbivores (DJ and RK pers. obs.).

The high shrub density in GPH foraging sites probably resulted from the deposition of seeds in the rain of faeces produced by vertebrate frugivores. This 'seed-rain' and the resulting seedling growth (Guevara *et al.* 2004) may have accounted for the increased density of shrubs beneath GPH foraging sites.

The *Ficus* taxa, with its multitude of coexisting species, contributes significantly to the diversity of tropical forests (Harrison 2005), and thus warrants conservation measures. Frequent lopping of branches, although not often lethal to the tree, results in stunted vegetative growth, and may negatively affect production of fig fruits. This could adversely limit food and nutritional availability (O'Brien *et al.* 1998; Wendeln *et al.* 2000) for frugivores, and thus affect the survival of GPH. Given the critical roles played by hornbills as seed-dispersal agents (Kinnaird 1998; Kitamura *et al.* 2004), it follows that systemic lopping of fig trees could lead to serial local extinctions within forest ecosystems by jeopardizing key plant-animal interactions. While it is encouraging that this study helped in enacting a ban on fig tree lopping in the Sanctuary, it is imperative that this policy be enforced on a consistent basis. Also, forest management training programs at state and national levels must incorporate and stress the importance of conservation of fig trees in maintenance of wildlife populations.

This case can be an example of positive conservation work that can be accomplished when scientists and local forest departments work cooperatively.

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27. THREE NEW ADDITIONS TO THE NON-INDIGENOUS FLORA OF ANDAMAN ISLANDS, INDIA[1]

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During a botanical exploration in the Little Andaman Island, the authors collected three plant species, which have been identified as *Pentapetes phoenicea* L. (Sterculiaceae), *Asclepias currasavica* L. (Asclepiadaceae), and *Acorus calamus* L. (Araceae). The literature on the floristics of Andaman and Nicobar Islands shows that occurrence of these taxa from the union territory has not been reported earlier (Vasudeva Rao 1986; Mathew 1998). The present communication gives a current nomenclature, brief description, distribution and ecology.

Pentapetes phoenicea L., Sp. Pl: 698. 1753; Mast. in Hook.f., Fl. Brit. India 1: 371. 1874; Ridl., Fl. Mal. Pen. 1: 284. 1922; C. Phengklai, Fl. Thai. 7(3): 595. 2001. *P. angustifolia* Bl., Bijdr.: 87. 1825.

Annual herb, *c*. 80 cm high. Leaves simple, narrowly lanceolate, 3.0-14.0 x 0.5-1.5 cm, apex acuminate, base obtuse, margin serrate to serrulate. Flowers pink. Sepals 5, narrowly triangular. Petals bowl-shaped. Stamens in 5 groups; staminodes 5, inserted between the group of stamens, both surrounding the ovary. Ovary ovoid, hairy, 5-locular.